# S-200VE Vega-E
# (SA-5B Gammon)
# Long Range Surface to Air Missile System
# Simulator Documentation

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## Preface

"200" the longest range SAM system of the Cold War, was developed by KB-1 under the leadership of AA Raspeltin. It was also the first Soviet SAM system that used the continuous wave target tracking method, a semi active radar guided hypersonic missile, and had a built-in digital computer. The Soviet Union fielded the first version in 1967, near Tallin thus it was called the "Tallin" system in the west. The "200" was constantly improved during its lifetime, resulting in the S-200 Angara and S-200V Vega (SA-5A), the S-200M Vega-M (SA-5B), and the S-200D Dubna (SA-5C) variants. The S-200M Vega-M's export version, the S-200VE Vega-E was exported to ten countries (Bulgaria, Czechoslovakia, Hungary, GDR, Poland, Iran, Libya, Mongolia, North Korea and Syria). Hungary operated it between 1986 and 1997. The Hungarian Vega battery participated in one live firing exercise in 1987 at Asuluk in the Soviet Union.

This program simulates the export version, the S-200VE Vega, (SA-5B Gammon).

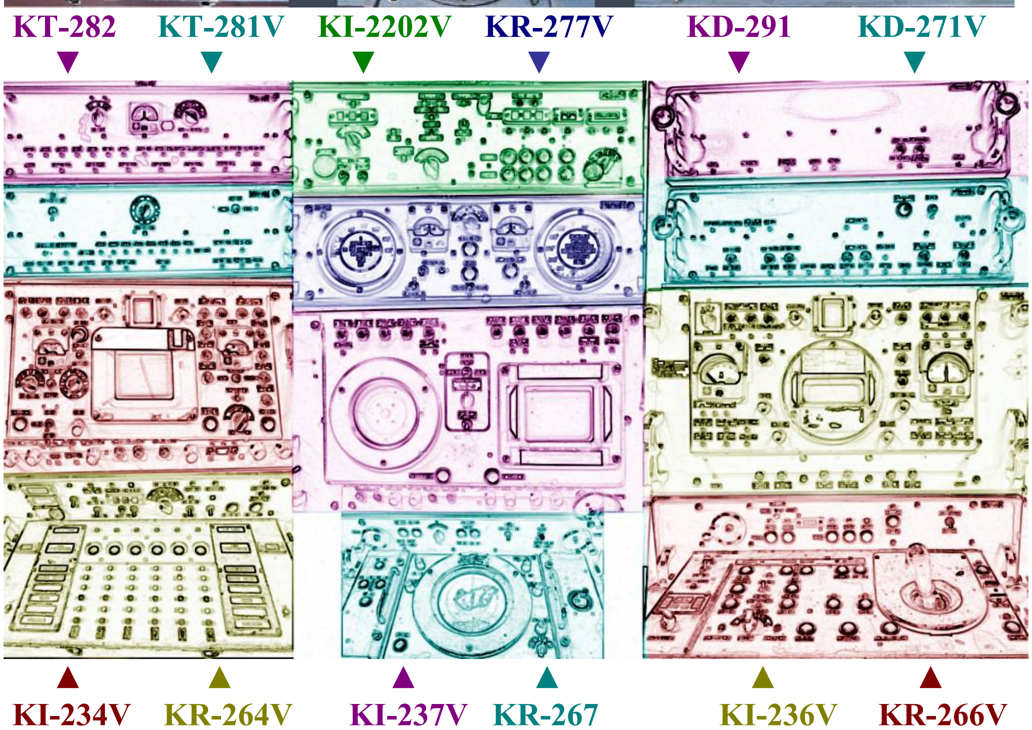
## Requirement to run this program

Your computer must be able to display a resolution of 1280x1024.
The program is not tested at any other resolution.

## Control Panel Designations and Keyboard References:

**Fire Control Officer, Target Acquisition Officer, Target Tracking Officer**

KI-23 Panel KI-22 Panel KI-21 Panel




**Fire Control Officer**'s instruments can be called up by pushing the button:
"**Z**" - (**KI-234V**, **KR-264V**), or "**A**" – (**KI-234V**), or "**Q**" – (**KT-282**)

**Target Acquisition Officer**'s instruments can be called up by pushing the button:
"**W**" - (**KI-2202V**, **KR-277V**), or "**S**" - (**KI-237V**), or "**X**" – **KI-237V**, **KR-267**)

**Target Tracking Officer**'s instruments can be called up by pushing the button:
"**D**" - (**KI-236V**), or "**C**" – (**KI-236V**, **KR-266V**)

**Plotting Table** can be called up by pushing the button: "**E**"

## Engagement Zone

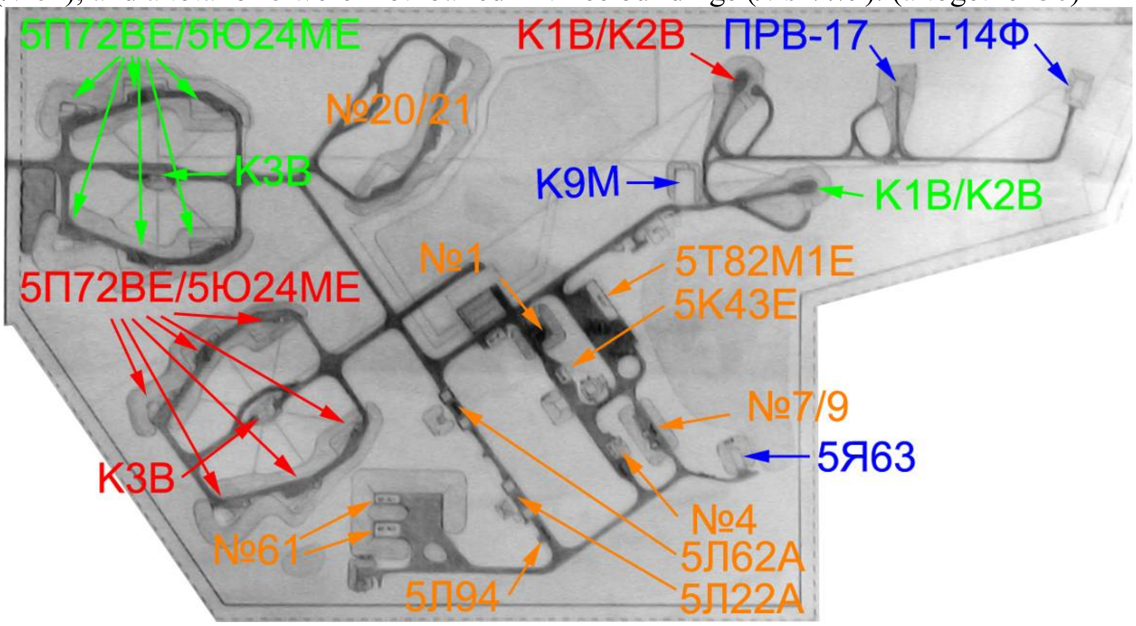
A single S-200VE Vega-E battery has one target channel, meaning that it can track one target, and launch six missiles onto it. One site can contain two, three or five collocated batteries. The maximum flight parameters of the target are 1200m/s (Mach 4) in speed, 255km (140 nm) in range, and 40.8km (135,000ft) in height.

The Vega barrier of the Warsaw Pact (formed at 8 sites with 18 batteries)


At the end of the 1980's, the Vega-E barrier of the Warsaw Pact (except USSR) contained;
3 batteries at Mrzezyno (Poland)
2 batteries each (total 8) at Pragendorf, Badingen, Wendgraben, and Eckolstadt (GDR)
3 batteries at Dobris, and 2 batteries at Rosice (Czechoslovakia)
2 batteries at Mezőfalva (Hungary)

## S-200VE VEGA-E (SA-5B Ganef) Site Layout

This example site contains two batteries occupying an area of 1.1km², ten times that required by earlier systems. During peacetime two pair of ready to launch missiles were on the ZM (rail loaders), a total of 24 assembled missiles were stored in two buildings (№61), and a total of 8 were mothballed in three buildings (№s1/7/9). (altogether 36)




**Battalion assets:**

*К9М* : K9M battalion management center cabin

*П-14Ф*: P-14F Obrona (Tall King-B) target acquisition radar

*ПРВ-17*: PRV-17 (Odd Pair) height finder radar

*5Я63*: 5Ya63 microwave relay connection to the IADS system

**Firing battery No1, No2 assets:**

*К1В/ К2В*: K1V (5N62VE RPC) target illuminator radar and K2V fire management cabin

*К3В*: K3V launch preparation cabin

*5П72ВЕ/5Ю24МЕ*: Six 5P72VE PU missile launchers per battery, capable of holding one missile each, and two 5Yu24ME ZM missile loaders per launcher, each carrying one missile for a total of two reserve missiles per launcher.

**Technical battery assets:**

*5Т82М1Е:* 6 TZM missile transporters per battery, (total 12)

*№1*: storage area for 6pcs mothballed V880E missile second stages

*5К43Е*: AKIPS, missile systems checking area

*№7/9*: storage area, for the mothballed boosters and warheads

*№4*: missile assembly area (joining 1st, 2nd stage, and the warhead)

*№61*: buildings holding 4pcs 5Ya83 assembled missiles storage rail per battery, (total 8) capable of storing 3 assembled missiles per rail. (altogether 24 assembled missiles)

*5Л94*: 5L94 high pressurized air filling station

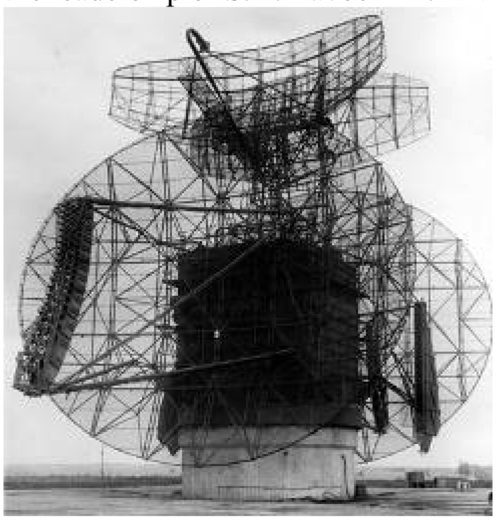
*5Л22А*: 5L22A “G” material (fuel) filling station

*5Л62А*: 5L62A “O” material (oxidizer) filling station

*№20/21*: missile defueling, and decontamination area

## S-50 Dal, with the 5V11 V400 missile (SA-5 Griffon)

In competition with the "200" SAM system was the S-50, developed by OKB-301 under the leadership of S.A. Lavochkin. In the west it was called the "Leningrad" system.



Five complexes were planned to defend Leningrad.

Instead of the two, three, or five single channel 5N62 RPC's of the S-200 design, the 5N21 19-27dm wavelength and 18m wide multichannel antenna system was planned by the "Dal" design. Its complicated 15rpm rotating double radar system would scan 360 degrees azimuth, and guide several missiles, onto multiple targets simultaneously.

The two stage, 16.3m long, and 8,757kg missile used command guidance to get to the vicinity of the target, then switched to onboard active radar guidance on the final phase.

During the October of 1962, the competition was ceased, and the S-200 system was announced as a winner. Soviet industry at that time was unable to create reliable active guidance head for the V400 missile. To deceive the west, the remaining missiles were paraded on the Red Square, from 1963. This effort was successful and confused NATO intelligence officers designated the S-50 as the SA-5 Griffon.

## Switching the Simulator On

(Press the “W” button on your keyboard to call up Target Acquisition Officer’s KI-2202V panel)


1. The startup mode selector switch should be switched to “Starting Up” (**ВКЛ.**) state, by clicking on it with the right mouse button.

2. The (**ВКЛЮЧЕНИЕ**) lamp will flash, indicating the power-up state of the system.

3. Clicking on the (**ВКЛ. К1В**) button, we turn on the K1V 5N62VE RPC (Square Pair) target illuminator radar.


4. Clicking on the (**ВКЛ. К2В**) button, we turn on the K2V fire control cabin, where we sit.

5. Clicking on the (**ВКЛ. ПР**) button, we turn on the power supply of the K1V 5N62VE RPC (Square Pair) target illuminator radar.

6. Clicking on the (**ВКЛ. ↯**) button, we turn on the high voltage of the K1V 5N62VE RPC (Square Pair) target illuminator radar.


7. When we turned on all the four subsystems, the (**ВКЛЮЧЕНИЕ**) lamp will illuminate steadily, indicating that the system can be switched to running mode.

8. The startup mode selector switch should be switched to “Running” (**ГОТОВ.**) state, by clicking on it with the right mouse button.

## Switching the Simulator Off

(Press the “W” button on your keyboard to call up Target Acquisition Officer’s KI-2202V panel)


To switch the system off, you need to press the red button (9).

## Methods of Target Acquisition

There are two possible methods of target acquisition:
- Primary method is the integrated air defense system.
- Backup method is the battalion’s early warning radar P-14F (Tall King-B).

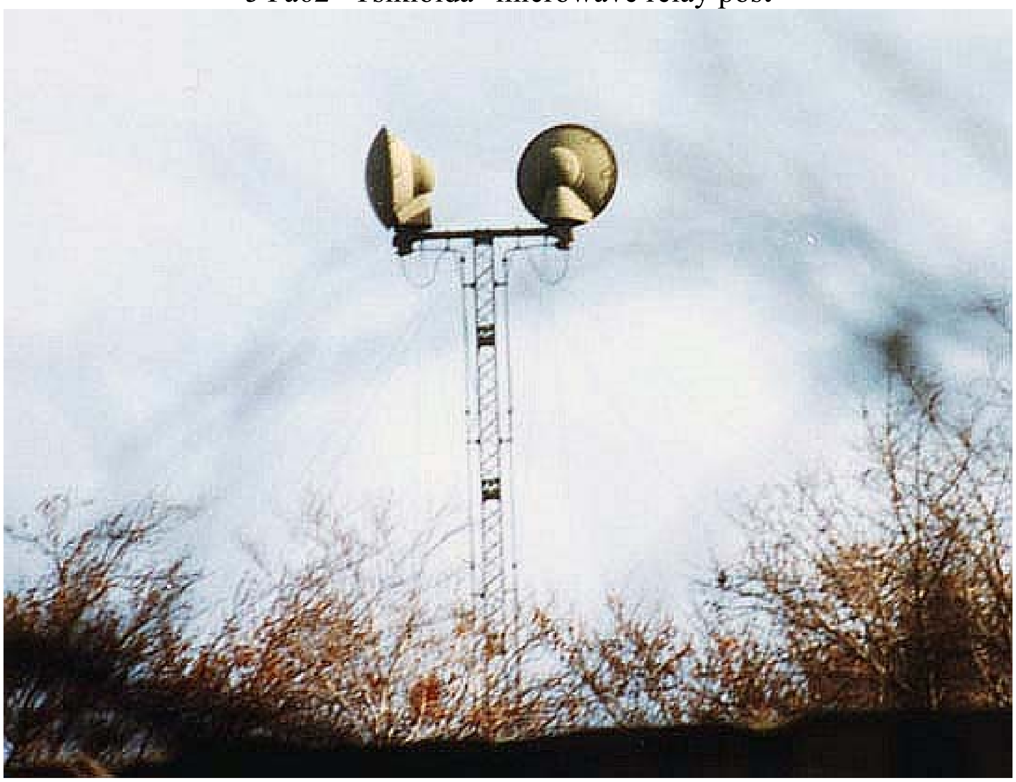
## *Senezh-ME, Integrated Air Defense System (IADS)*

IADS function is to automate pairing of targets with engagement weapons (fighters or SAMs). It uses information from radar battalions and a data link to transmit the designated target's location to the SAM battalion every once every 10 seconds. The SAM battery has two connections to the IADS:

- The main connection is by ground cable
- The backup connection is by the 5Ya62, 5Ya63 "Tsikloida" (microwave relay)

The IADS interface to the SAM battery is the 5F24 cabin.

5Ya62 "Tsikloida" microwave relay post



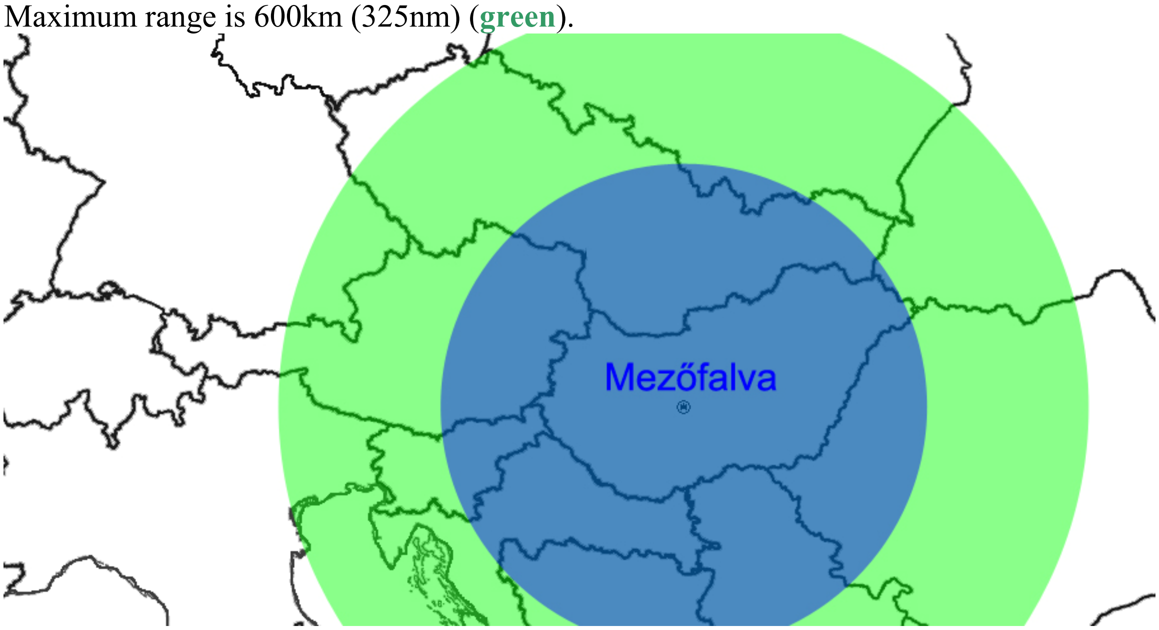
Fielded at Szarvaspuszta, during 1988, at the fortified base "50".
Capable of directing…

17 SAM batterys (SA-2 Guideline, SA-3 Goa, SA-5 Gammon, SA-10 Grumble), altogether 24 target channels and
MiG-21, MiG-23, MiG-25 fighter formations

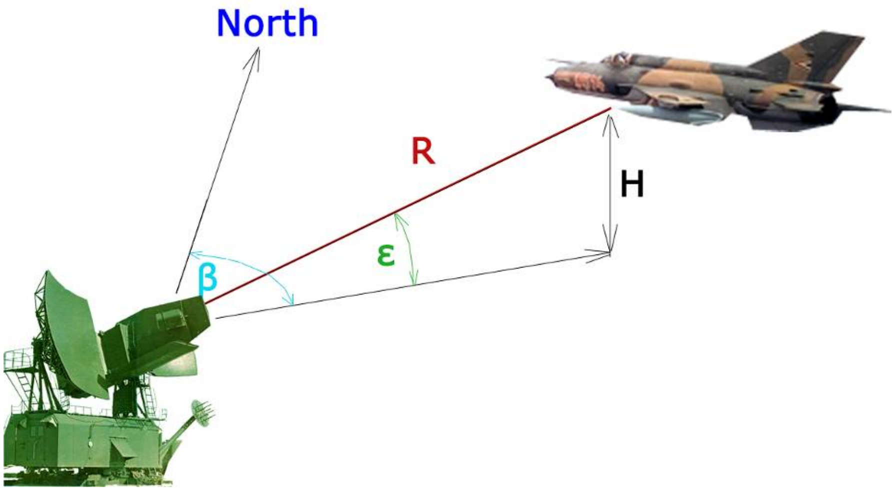
… automatically, against 50 hostile targets simultaneously.

## *P-14F Obrona (Tall King-B) Target Acquisition Radar*

The metric wavelength, 11m high and 32m wide P-14F target acquisition radar has a detection range for small sized targets (MiG-21) of around 360km (195nm) (**blue**). Maximum range is 600km (325nm) (**green**).



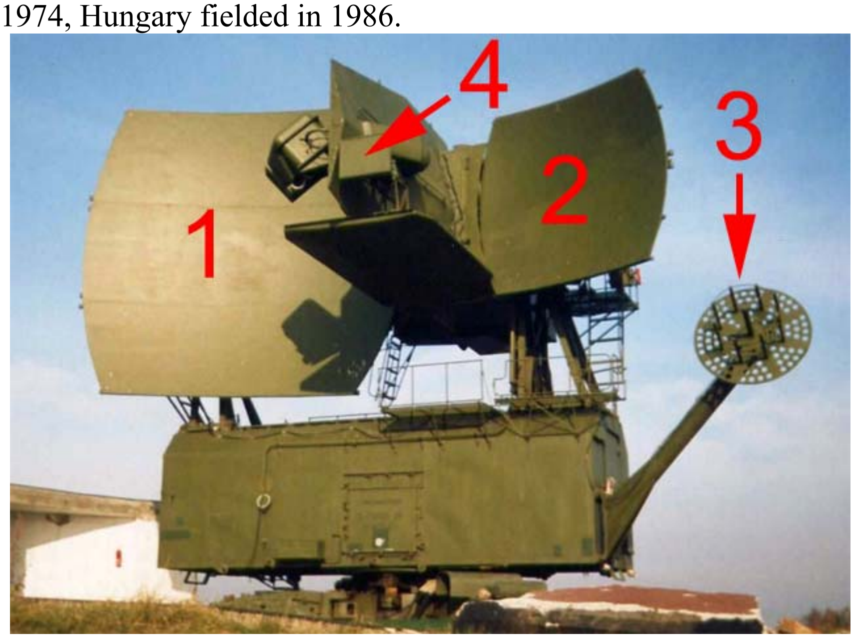
## Parametric Coordinate System




R – target range
H – target height
ε (epsilon) – elevation angle (antenna up - down)
β (beta) – azimuth angle (antenna left - right)

## 5N62VE RPC (Square Pair) Target Illuminator Radar

Built since 1974, Hungary fielded in 1986.




1. Continuous 4.5cm wavelength target illumination signal, transmit-only antenna
2. Continuous 4.5cm wavelength target illumination signal, receive-only antenna
3. KRO missile flight status down-link signal, receive-only antenna.
4. NRZ (IFF) antenna

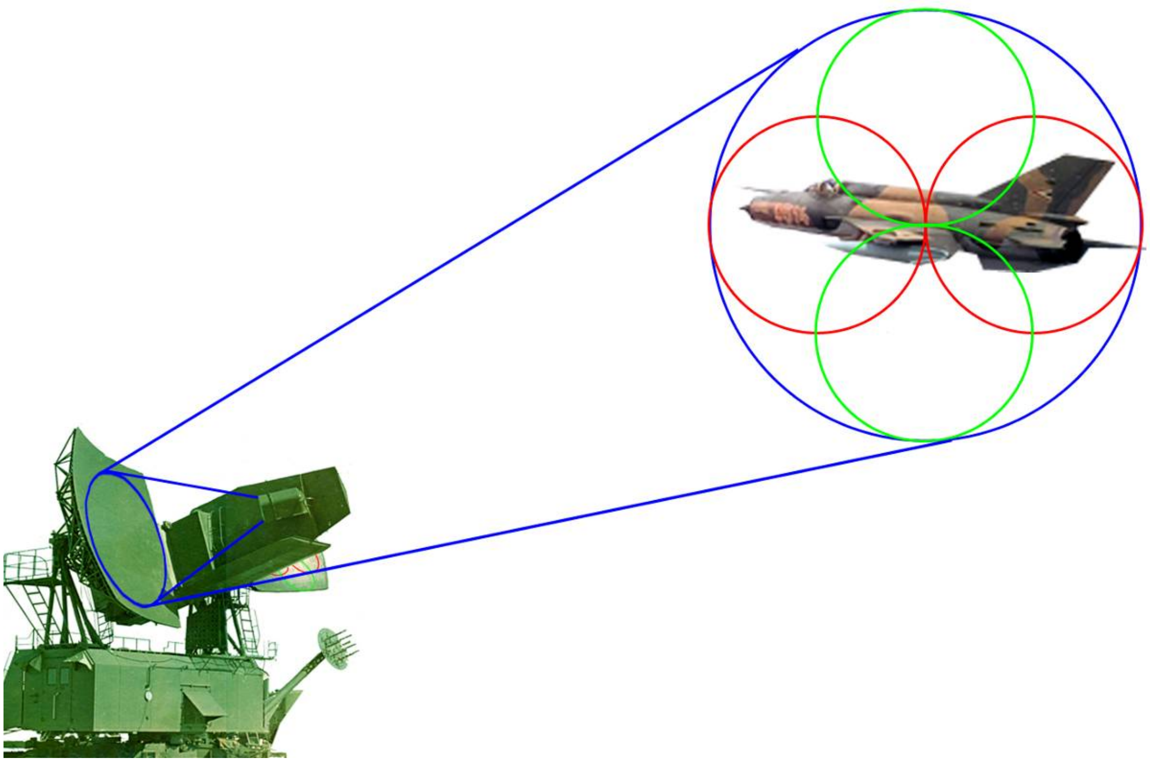
The 5N62VE RPC has a detection range for small sized targets (MiG-21) of around 300km (160nm). Maximum range is 500km (270nm).

## *5N62VE RPC (Square Pair) Mode of Operations*

The RPC mode of operations can be classified by the emitted beam shape, wave form, and the target tracking method.

### ШИР. (wide) or УЗК. (narrow) pencil beam

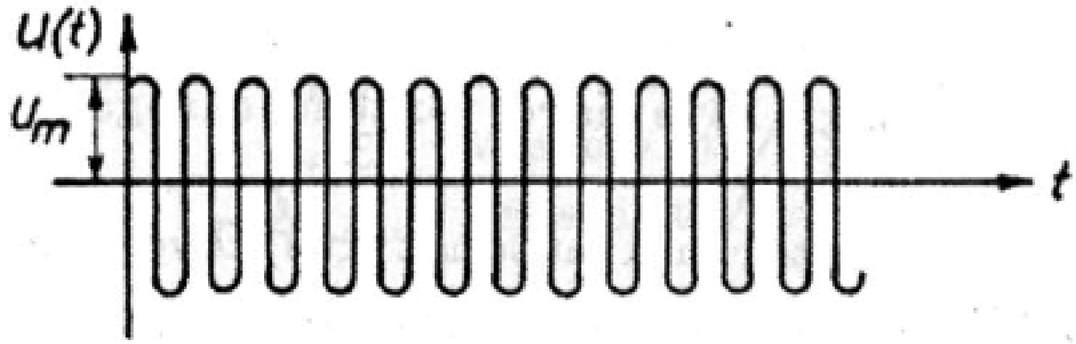
The 1.4º wide pencil beam is used during target acquisition, if the target is closer than 200km.
The 0.7 º narrow pencil beam is used during target acquisition, if the target is further than 200km, and during target tracking.



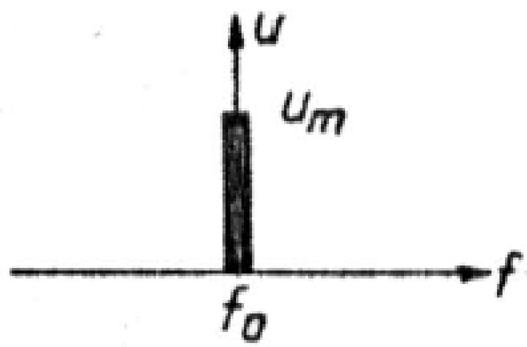
The continuous wave signal is emitted in the (blue) pencil beam. The reflected signal is received by the smaller square antenna, splitting it into three beams, (blue, red, green), where two beams are double pencils (red, green). The target tracking system seeks to minimize the signal across the two double pencils and maximize the signal at the blue pencil beam.

### МХИ (MHI) Mono-Chromatic Emission

MHI is the primary mode of the RPC, emitting a continuous sinusoidal wave.



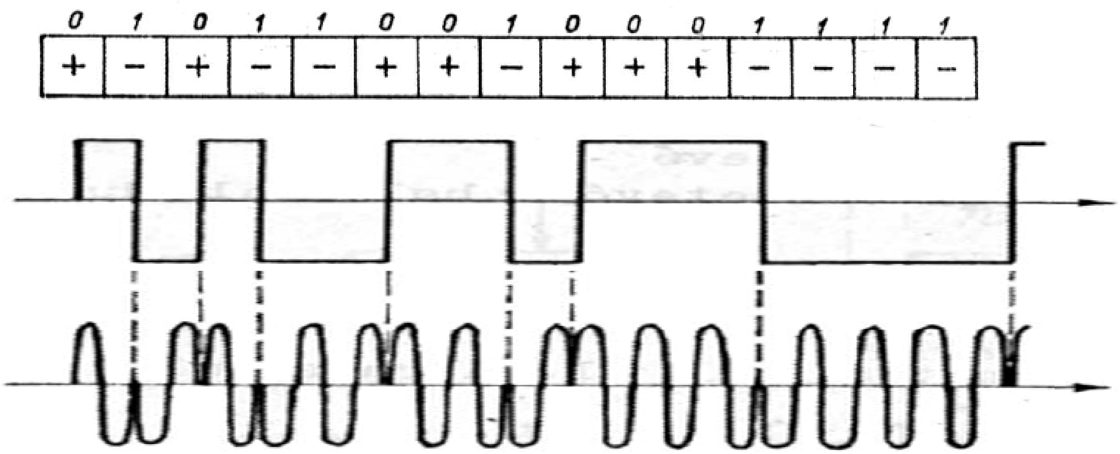

The returned radar echo's Doppler shift is measured.
With this mode, the target's speed, elevation, and azimuth are measured.
Auto target tracking using this mode is called **AS-3**.
As the emitted energy is in a very narrow frequency spread, the target detection range is the best in this mode.



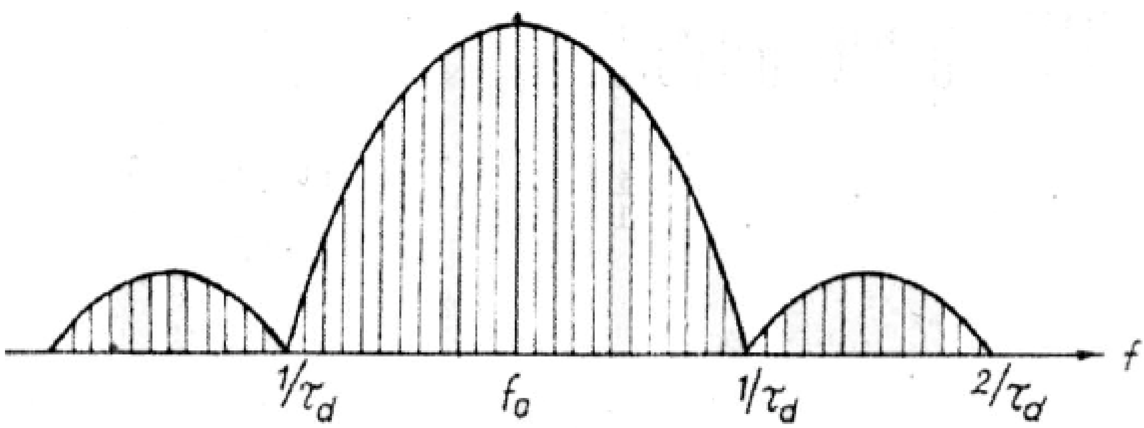

If the target's angular speed is less than 40 m/s (78 knots) (the target is on tangential path), it cannot be detected using this mode

## ФКМ (FKM) Phase-Code Manipulation

FKM mode of the RPC, is used to measure target range also.
During this mode, the emitted sinusoidal wave is phase modulated by a digital code.




With this mode, beside the target’s speed, elevation, and azimuth, its range is also measured. The auto target tracking using this mode is called **AS-4**.
As the emitted energy is across a wider frequency spread, the target detection range is shorter than in MHI.




If the target's angular speed is less than 60 m/s (117 knots) (the target is on tangential path), it cannot be detected using this mode.

## ЧМ (FM) Frequency Modulation

FM is a sub mode of the RPC, it can be used with MHI, or FKM.
During this mode, the emitted sinusoidal wave is frequency modulated.
As the emitted energy is across a wide frequency, the target detection range is even shorter than in MHI or in FKM.
The advantage of using this mode is that the target's angular speed can be zero and still be tracked in azimuth and elevation.

## АС-РПЦ (AS-RPC)

AS-RPC is a sub mode of the RPC, it can be used with MHI, or FKM.
During this mode, the digital computer is continuously calculating the target's predicted path. In case the target's angular speed drops below the minimum, and the target cannot be tracked using the FM sub mode, the RPC will track the target's predicted path.

## Plamja-KV CVM (digital computer)

The digital computer has a 16bit processor, running at 64kHz frequency.
It has 256 bytes of RAM, and 4,096 bytes of ROM.

It has five built-in programs:

**1. Idle**
In this mode, the Plamja-KV is calculating the firing solution using the instantaneously available data from the RPC.

**2. IADS target acquisition**
In this mode, the Plamja-KV is interpolating the target's predicted position, between the 10Hz updates received from the IADS information.

**3. Target tracking**
In this mode, the Plamja-KV is continuously calculating the target's predicted path, and figuring the firing solution based on this information.

**4. Tracking Jamming Target**
In this mode, the Plamja-KV is calculating the firing solution using a manually preset target range. This mode is called **AS-2**.

**5. Self Test**

## *Moving the 5N62VE RPC (Square Pair) Target Illuminator Radar*

The RPC target illuminator Doppler radar can be aimed in 4 coordinates.
ε - elevation
β – azimuth
v – speed
d - range

## Rotate the 5N62VE RPC (Square Pair) Target Illuminator Radar in Azimuth and Elevation

(Press the "X" button on your keyboard to call up Target Acquisition Officer's KR-267 panel)


(Press the "W" button on your keyboard to call up Target Acquisition Officer's KI-277V panel)


1. To be able to rotate the 5N62VE RPC (Square Pair) target illuminator radar in azimuth and elevation, you need to switch it into manual mode, by clicking on the red "CU off" (**ЦУ ВЫКЛ.**) button.
2. In manual mode (**МД**), the two (azimuth/elevation) red lamps will illuminate.
3. To rotate the 5N62VE RPC (Square Pair) target illuminator radar in azimuth, you need to hold down the left mouse button over the right wheel, and move it right-left.)
4. The flashing line on the P-18F (Tall King) indicator shows the azimuth of the RPC.
5. The indicator hand on the right round instrument of the KR-277V panel shows also the azimuth of the RPC.
6. To move the 5N62VE RPC (Square Pair) target illuminator radar in elevation, you need to hold down the left mouse button over the right wheel, and move it right-left.)
7. The indicator hand on the left round instrument of the KR-277V panel shows the elevation of the RPC.
8. By clicking on the red "Return" (**ВОЗВРАТ**) button, the RPC elevation can be set back to zero.

## Set the 5N62VE RPC (Square Pair) Target Illuminator Radar Speed and Range Gates

(Press the "C" button on your keyboard to call up Target Tracking Officer's KI-236V, KR-266V panels)


1. To be able to set the 5N62VE RPC (Square Pair) target illuminator radar speed gate, you need to switch into the manual mode, by clicking on the (**V-МД**) button. The (**МД**) red lamp will illuminate above it.

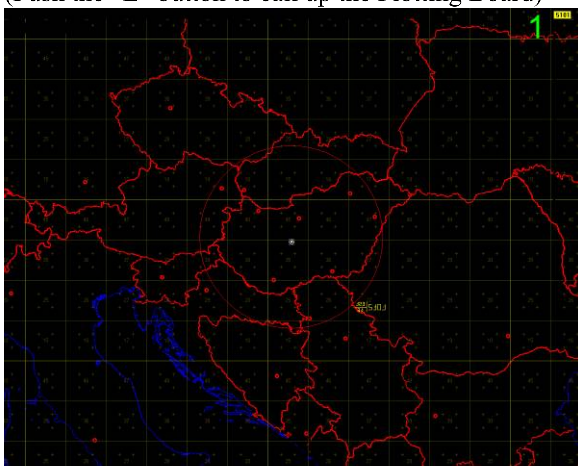
2. To set the 5N62VE RPC (Square Pair) target illuminator radar Doppler speed, you need to hold down the left mouse button over the joystick, and move it right-left.
3. The hand on the right instrument of the KI-236V panel shows the speed in m/s.

4. To be able to set the 5N62VE RPC (Square Pair) target illuminator radar range gate, you need to switch it into manual mode, by clicking on the (**Д-МД**) button. The (**МД**) red lamp will illuminate above it.
5. To set the 5N62VE RPC (Square Pair) target illuminator radar in range, you need to hold down the left mouse button over the wheel, and move it right-left.
6. The hand on the left instrument of the KI-236V panel shows the range in km.

## Target Acquisition using Senezh-ME, IADS

This is the primary method of target acquisition.

(Push the “E” button to call up the Plotting Board)




1. Clicking the target number in the plotting table, we can select automatic target acquisition.

(Press the “X” button on your keyboard to call up Target Acquisition Officer’s KR-267 panel)


2. Clicking on the “**ЦУ ВКЛ**.” button, we turn the RPC towards the IADS target.
3. The “**ε ЦУ**” green lamp will flash, while the RPC is rotated towards the target in elevation.
4. The “**β ЦУ**” green lamp will flash, while the RPC is rotated towards the target in azimuth.

Both lamps will illuminate steadily, when the RPC is pointing to the target.

(Press the “C” button on your keyboard to call up Target Tracking Officer’s KI-236V, KR-266V panels)


5. Clicking on the “**ГЛАДКИЙ**” (flat) button, we select MHI (Mono Chromatic Emission) to maximize target acquisition range.
6. Clicking on the “**Д ЦУ**” button, we set the RPC range towards the IADS target.
7. Clicking on the “**V ЦУ**” button, we set the RPC Doppler velocity towards the IADS targets angular velocity.

Both lamps will illuminate steadily, when the RPC’s range and Doppler speed are set.

8. If the target is further than 200km, we set the RPC’s beam to “**УЗК.**” (narrow) with the “**ДИАГРАММА**” switch (9).

(Press the “W” button on your keyboard to call up Target Acquisition Officer’s KI-2202V panel)


10. We turn on the transmitter by rotating the “**МОЩНОСТЬ**” (power) switch to the left-most “**ПОЛН.**” setting.

(Press the “C” button on your keyboard to call up Target Tracking Officer’s KI-236V, KR-266V panels)


11. When the target appears between the Doppler velocity gates, on the DV indicator, we switch the RPC to AS-3 target tracking, by clicking on the “**АСЗ**” button (12). If the tracking is successful, the “**V**” lamp will illuminate.
13. We set the CVM (digital computer) to full target tracking, by clicking on “**ВКЛ. АС РПЦ**”.

## Target Acquisition using the P-14F Acquisition Radar

This is the backup method of target acquisition, in case the IADS is not available.

(Press the “X” button on your keyboard to call up Target Acquisition Officer’s KR-267 panel)


1. The P-14F indicator has inscribed map for the 400km displayed range.
2. The displayed range can be set for 100km, 200km, 400km, or 600km.
3. The range rings are at every 50km.
4. The RPC’s range gate is indicated by the dashed ring.
5. The RPC’s azimuth bore sight is indicated by a flashing line.
6. We move the RPC’s azimuth bore sight onto the target (7) by holding down the left mouse button over the wheel, and moving it to right-left.

(Press the “C” button on your keyboard to call up Target Tracking Officer’s KI-236V, KR-266V panels)


8. Clicking on the “**ГЛАДКИЙ**” (flat) button, we select MHI (Mono Chromatic Emission) to maximize target acquisition range.
9. If the target is further than 200km, we set the RPC’s beam to “**УЗК.**” (narrow) with the “**ДИАГРАММА**” switch.
10. We set the target's expected angular Doppler velocity by holding down the left mouse button over the joystick, and moving it to right-left. It can be read off from the right instrument (11).

## *Understanding the DV Indicator in MHI Mode*

(Press the "D" button on your keyboard to call up Target Tracking Officer's KI-236V panel)


In MHI (Mono Chromatic Emission) mode, the DV indicator is showing the target angular Doppler velocity only. In the center of the middle band is the Doppler velocity gate (Vd), matching the speed that is indicated in the instrument at the right. On that instrument, approaching targets use speeds on the right side of the instrument, receding targets use speeds on the left side of the instrument. The DV Indicator displays a speed range from -1Mach below to +1Mach above the selected Doppler velocity.

If the expected target is an average fighter, than we can set the angular Doppler velocity to 300m/s (1Mach), so the target will appear if it goes between 0-2Mach.
If we expect an incoming high-speed target (SR-71), than we can set the angular Doppler velocity to 600m/s (2Mach), so the target will appear if it goes between 1-3Mach.

(Press the "W" button on your keyboard to call up Target Acquisition Officer's KI-2202V panel)


11. We turn on the transmitter by rotating the "**МОЩНОСТЬ**" (power) switch to the leftmost "**ПОЛН.**" setting.

If the target cannot be seen on the DV indicator, we should start a search for it.

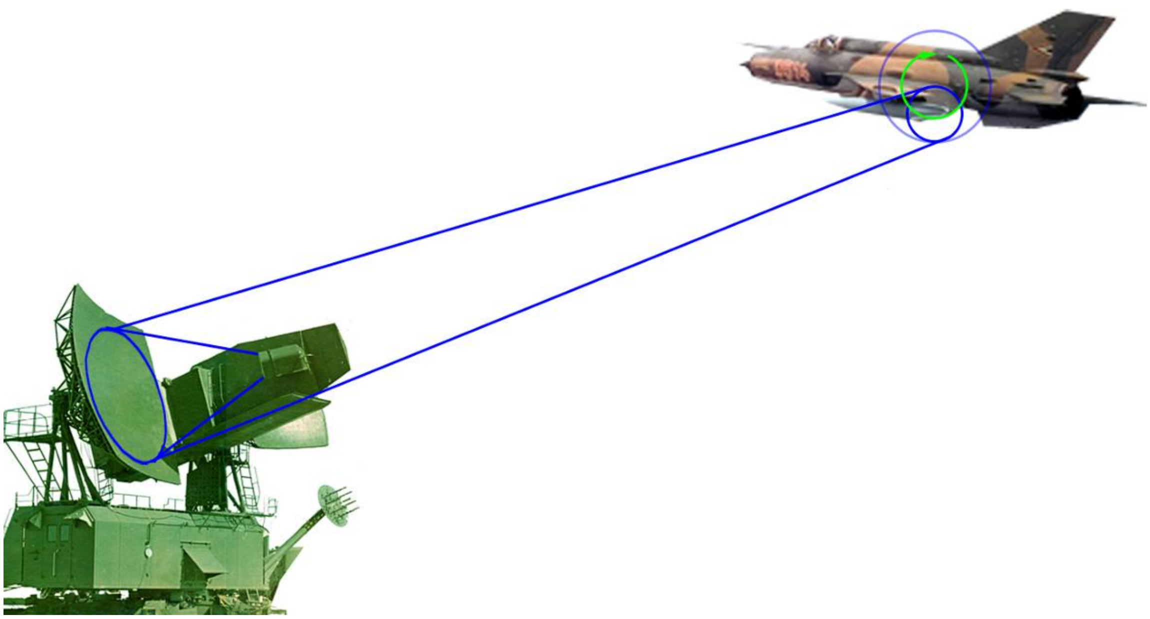
## *Circular Target Search*

(Press the “X” button on your keyboard to call up Target Acquisition Officer’s KR-267 panel)


12. We click on the “**КРУГОВОЕ**” button, to start the circular search. The round instrument is showing elevation “ε” in the vertical, azimuth “β” in the horizontal, and Doppler velocity in the radial direction.

13. If the target is discovered, displayed as a bright dot, we click on the “**ВЫКЛ**” button (14) to stop the search, and acquire the target.

If the target cannot be found during one rotation, we start the Sector search. First we click on the “**ВЫКЛ**” button (14) to stop the Circular search…



Note that in Western terms, this would be called Conical search.

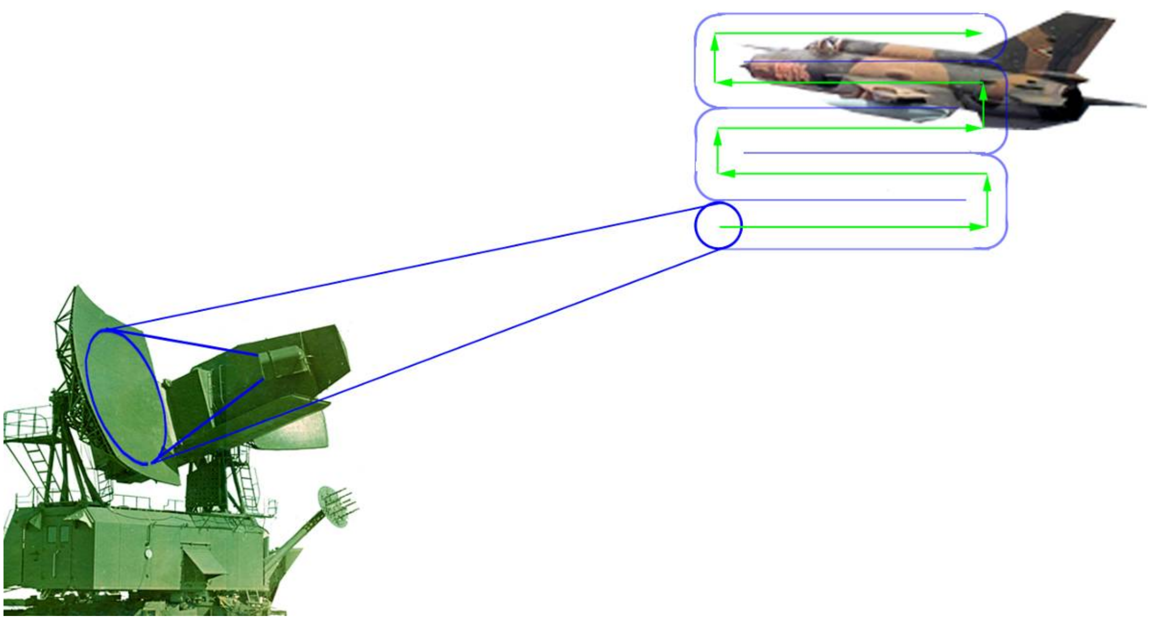
## *Sector Target Search*

(Press the “X” button on your keyboard to call up Target Acquisition Officer’s KR-267 panel)


15. Then we click on the “**СЕКТОРНОЕ**” button, to start the sector search. The round instrument is now showing azimuth “β” in the vertical, and Doppler velocity in the horizontal.

16. If the target is discovered, displayed as a bright dot, we click on the “**ВЫКЛ**” button (17) to stop the search, and acquire the target.

If the target cannot be found, we restart the Sector search, by clicking on the “**ВОЗВРАТ**” button (18).



## *Determining the Target Range in FKM Mode with "Nonius" (Vernier) Method*

(Press the "C" button on your keyboard to call up Target Tracking Officer's KI-236V, KR-266V panels)


19. We move the target mark (20) between the Doppler velocity gates, by holding down the left mouse button over the joystick, and moving it to right-left.

21. When the target moves between the Doppler velocity gates, we switch the RPC to AS-3 target tracking, by clicking on the "**AC3**" button (21). If tracking is successful, the "**V**" lamp will illuminate.


22. We click on the "**ПОЛОВИН**" button, to switch the RPC into half-FKM mode.

23. We click the "**НОНИУС**" button, to switch to the ***Rough Nonius*** mode. During this FKM mode, 450km range is displayed vertically, while the range uncertainty is 15km.

24. To move the target mark to the range gate, we need to hold down the left mouse button over the range wheel (25), and move it to right-left.


26. We click the "**CH**" button, to switch the ***Medium Nonius*** mode. During this FKM mode, 150km range is displayed vertically, while the range uncertainty is down to 5km.

27. To move the target mark to the range gate, we need to hold down the left mouse button over the range wheel (28), and move it to right-left.


29. We click the "**TH**" button, to switch the ***Fine Nonius*** mode.
During this FKM mode, 12km range is displayed vertically, and the range uncertainty is down to 400m.

30. To move the target mark to the range gate, we need to hold down the left mouse button over the range wheel (31), and move it to right-left.


32. We click the "**55**" button, to switch the ***55kHz mode***. The FKM code is repeated at 55kHz.
During this FKM mode, 2.7km range is displayed vertically, and the range uncertainty is down to 90m.

33. To move the target mark to the range gate, we need to hold down the left mouse button over the range wheel (34), and move it to right-left.


35. When the target is moved within the range gate, we switch the RPC to AS-4 target tracking, by clicking on the "**AC4**" button (36). If the tracking is successful, the "**Д**" lamp will illuminate.

37. We click on the "**ПОЛН**" button, to switch the RPC into full-FKM mode.

38. We set the CVM (digital computer) to full target tracking, by clicking on "**ВКЛ. АС РПЦ**".

We can switch the CVM (digital computer) to full target tracking at any Nonius mode (Rough, Medium, Fine, 55kHz), but we should just be aware of the range uncertainty we introduce into the CVM (digital computer) in doing this.
"**НОНИУС**" - Rough Nonius proportion - 15km range uncertainty.
"**CH**" - Medium Nonius proportion - 5km range uncertainty.
"**TH**" - Fine Nonius proportion - 400m range uncertainty.
"**55**" - 55kHz proportion - 90m range uncertainty.


39. We click on the “**ПОЛОВИН**” button, to switch the RPC into half-FKM mode.

40. Clicking on the “**ГЛАДКИЙ**” (flat) button, we select MHI (Mono Chromatic Emission) to maximize target acquisition range.

Be aware, that if we would switch the system from Full-FKM to MHI mode directly, the auto tracking would be lost.

## Factors that Limit the Effective Target Acquisition Range

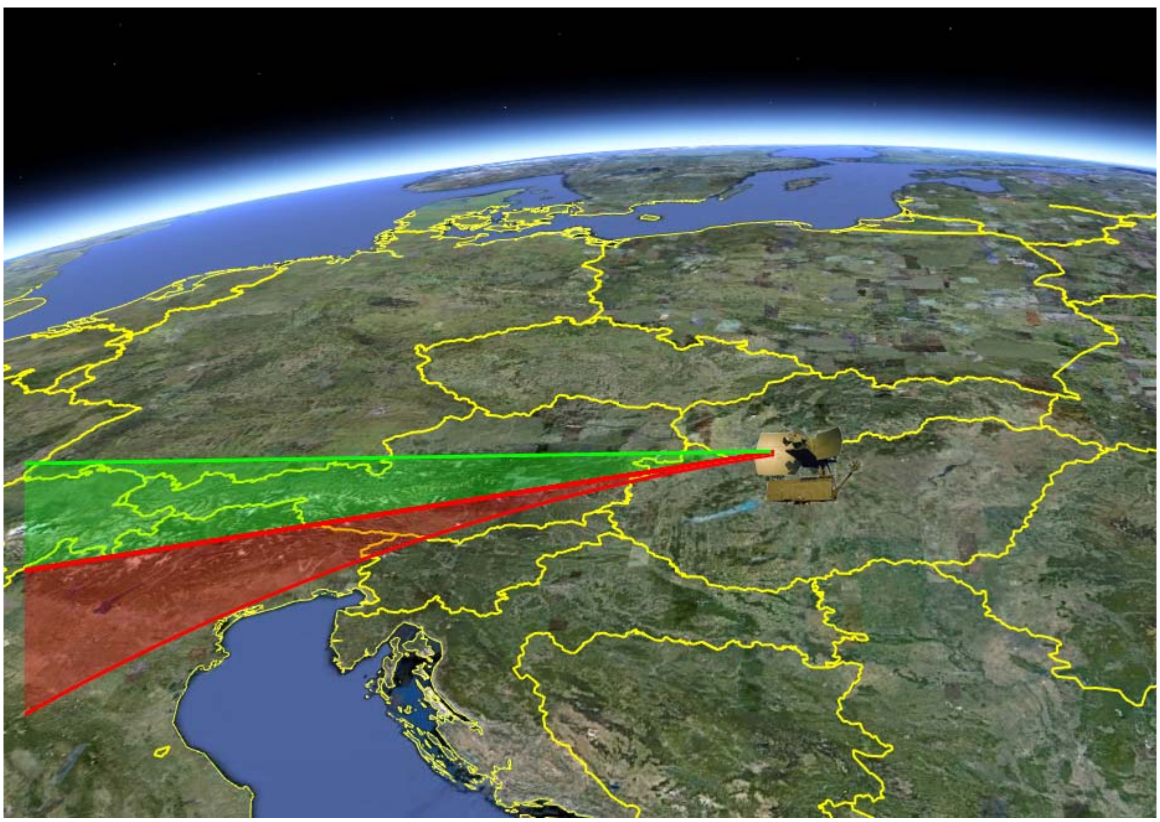
There are several factors that could make target acquisition unsuccessful.
The effective target acquisition range is dependent on three factors:

- Radar cross section of the target
- Earth curvature effect
- Angular velocity of the target

### *Radar cross section of the target*

The 4.5cm wavelength, continuous wave target illumination radar has 85kw continuous output but, its target detection range is still heavily dependent on the targets radar cross section. While big radar cross section targets (B-52, E-3A AWACS) could be detected theoretically at the maximum range of the RPC (500km), small sized fighters (MiG-21) could only be detected from about 300km.

### *Earth curvature effect*



Targets cannot be detected if they are flying below the radar horizon (red zone).

| Target altitude | 60m | 100m | 1000m | 3000m | 10000m | 15000m | 20000m |
|---|---|---|---|---|---|---|---|
| Max. detection range due to curvature | 45km | 50km | 130km | 210km | 370km | 450km | 520km |

## *Angular Velocity of the Target*

All Doppler radars are sensitive for low tangential velocity.


1. When the target angular velocity drops, the “**РАЗРЕШ. ЧМ**” (Switch on FM) red warning light (2) will illuminate.

There are two FM sub modes associated with the two main wave forms MHI, and FKM.

“**НЕПРЕРЫВ. ЧМ**” (continuous Frequency Modulation) is used, when the main waveform is MHI, and the “**ГЛАДКИЙ**” (flat) lamp is illuminated.


“**ПРЕРЫВ. ЧМ**” (periodical Frequency Modulation) is used, when the main waveform is FKM, and the “**ПОЛОВИН**” (half-FKM), or the “**ПОЛН**” (full-FKM) lamp is illuminated.

3. The FM mode selector is switched to the required mode (“**НЕПРЕРЫВ. ЧМ**” – left, “**ПРЕРЫВ. ЧМ**” - right), and the associated green lamp (4) will illuminate.

5. As the emitted wave is frequency modulated, the signal received from the target will be much weaker then in the non-frequency modulated modes.


6. If the received signal is too weak, the auto tracking is lost, the “**ПРОЛОНГ.**” red warning light will illuminate, and the RPC will continue to track the predicted path of the target.

7. The FM mode should be switched off, to maximize the received signal strength.

After the target angular velocity leaves the red zone, it will reappear, and it can be auto tracked again.

## NCTR (Non Cooperative Target Recognition)

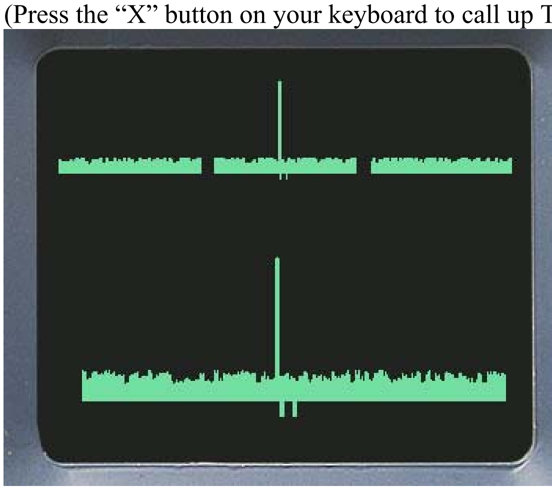
As we prepare to shoot at long ranges, where the time for the hypersonic missile to reach the target can be several minutes, we need to know more about the target type, to be able to assess its predicted behavior after launch.

Two parameters can be assessed,

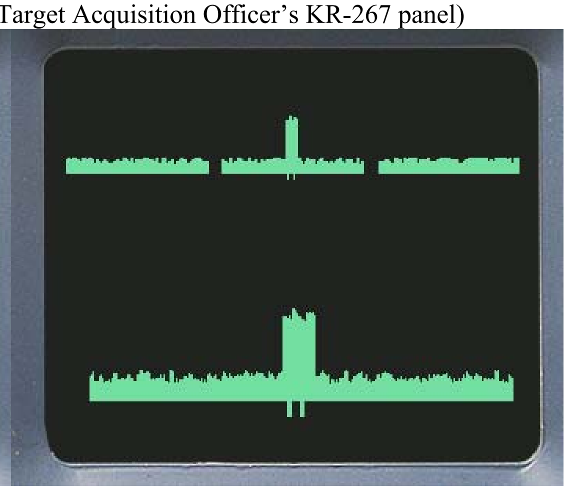
- Doppler frequency spectrum of the target, to assess its turbine components
- Received signal strength compared to the target's distance, to asses its size

### *Assessing the Doppler Frequency of Target's Turbine Components*

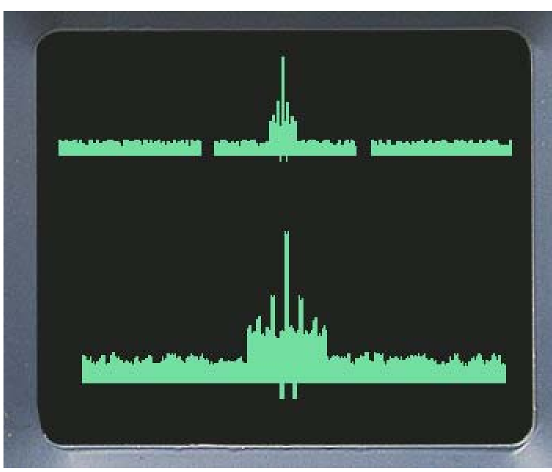
The high-speed spinning turbine blades of the target's engine add extra modulation to the frequency spectrum of the target return signal.
(Press the “X” button on your keyboard to call up Target Acquisition Officer’s KR-267 panel)



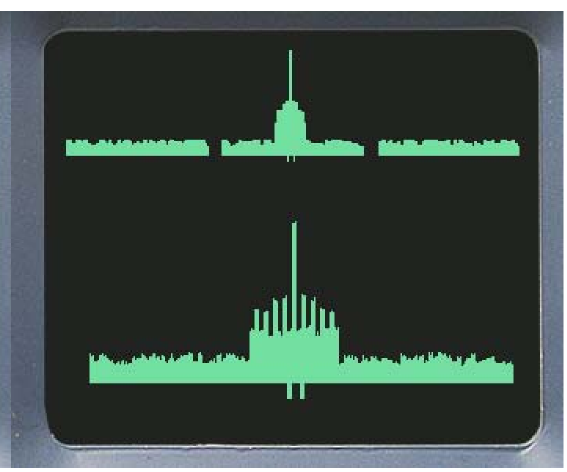
A missile has no turbine components and limited spectrum in its return.



A propeller driven plane, or helicopter has wide spectrum.



A single turbine plane has sparse turbine components.



A plane having more than one engine has dense turbine components.

## *Assessing the Received Signal Strength*

(Press the “C” button on your keyboard to call up Target Tracking Officer’s KI-236V, KR-266V panels)


First we read out the target distance from the “Д” instrument.

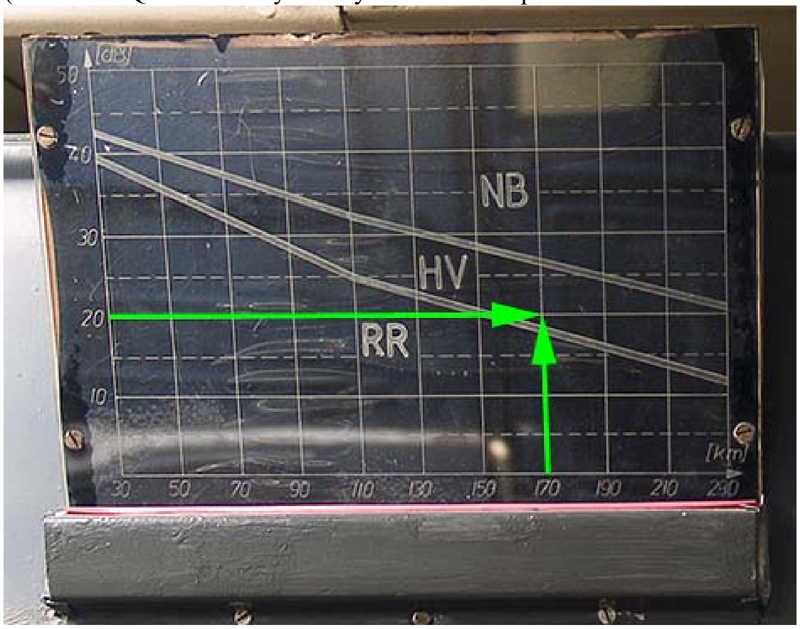
Currently it is **170km**

(Press the “A” button on your keyboard to call up Fire Control Officer’s KI-234V panel)


We read out the received signal strength from the “**УРОВЕНЬ СИГНАЛА**” (Signal level) instrument.

Currently it is **20dB**

(Press the “Q” button on your keyboard to call up Fire Control Officer’s KT-281V panel)




At the chart, we look out the type of the target.

170km and 20dB is at the lower part of the “**HV**” region, so the target is a small sized fighter.

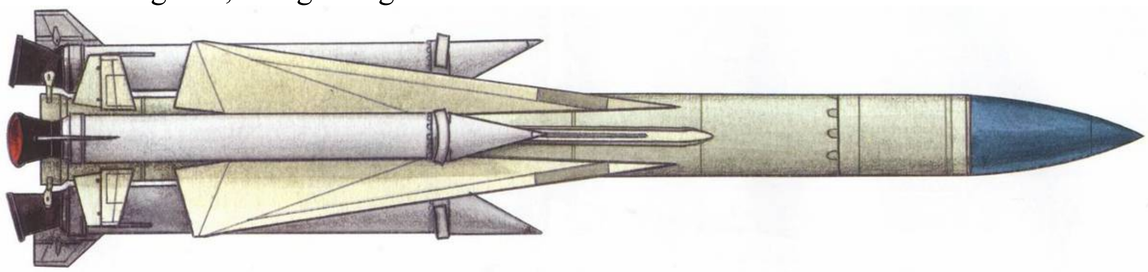
NB – “Nehézbombázó” Heavy Bomber

HV – “Harcászati Vadász” Fighter

RR – “Repülőfedélzeti Rakéta” Small missile

## 5V21 V-860P (SA-5A Gammon) Surface to Air Missile

Fielded from 1967, the first missile type of the S-200 Angara (SA-5A Gammon) system.
Launch weight: 6,700kg. Length: 10.4m.



←——————————1——————————→
←2——→←3→←——4——→←————5————→←——6——→←7→←8→←——9——→

1. **4pcs I. I. Kartukov - 5S25 PRD solid fuel booster.**
2. **S. Izotov - 5D12 ZRD digitally programmable liquid fuel sustainer.**
   Thrust: 32~100kN (depending on program)
   Burn time: 50~98s (depending on program)
   Maximum Range: 150 km
   Altitude (min/max): 1,000-35,000m
   Max missile speed: Mach4.5
   Min/Max target speed: 360km/h / Mach3.2
3. **Onboard electrical power source**
4. **TG-02 "Samine" fuel ("G" substance) tank.**
   Composition mixture of xilidine, and triethylamine.
   50% $C_8H_{11}N$, 50% $C_6H_{15}N$
   *Oily liquid, with color from yellow to dark-brown, and an odor typical for satured animes. Strong nerve agent, fatal concentration in air is: 18mg/liter!*
5. **AK-27P "Melanj" oxidizer ("O" substance) tank.**
   Composition: Nitric Tetroxide in solution with Nitric Acid, with Phosphoric and Fluoric acid inhibitors.
   26±2% $N_2O_4$, 69,5% $HNO_3$, 0,1% $H_3PO_4$, 0,4±0,1% HF, 1,2±0,5% $H_2O$
   *Orange-brown, evaporating liquid. Self ignites combustibles. Highly corrosive, only few materials can withstand its effect: chromium steel, pure aluminum, glass, and for a short period, some rubber mixes.*
6. **5B14S Warhead**
7. **5A41 autopilot, 5E22 SRP digital flight computer**
8. **5G23 GSN Continuous Wave semi-active seeker**
9. **Radome**

## 5V21N V-870 (SA-5A Gammon) Surface to Air Missile

The V870 was employed a nuclear warhead, instead of the conventional used by the V860P.

## 5V21V V-860PV (SA-5B Gammon) Surface to Air Missile

Fielded from 1969, the first missile type of the **S-200V Vega (SA-5B Gammon)** system, that introduced the P-14F (Tall King B) metric target acquisition radar, with the PRV-13 (Odd Pair) height finder. The new 5G24 CW seeker had enhanced jamming resistance. The missile's maximum range was increased to 180km range, while the target's minimum angular speed was reduced to zero, and minimum altitude was reduced to 300m.

## 5V28 V-880 (SA-5B Gammon) Surface to Air Missile

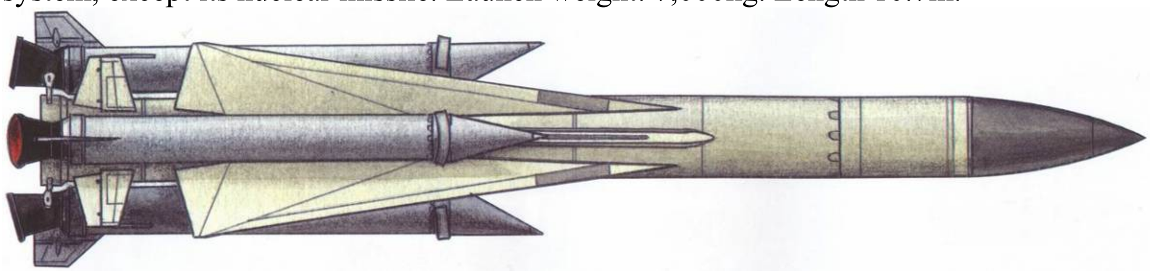
Fielded from 1974, the first missile type of the **S-200M Vega-M (SA-5B Gammon)** system, with extended maximum range.

## 5V28N V-880N (SA-5B Gammon) Surface to Air Missile

The V880N was employed a nuclear warhead, instead of the conventional used by the V880.

## 5V28E V-880E (SA-5B Gammon) Surface to Air Missile

Exported from 1982, the only version available outside of the Soviet Union, the **S-200VE Vega-E (SA-5B Gammon)** system, had the same capabilities as the S-200M Vega-M system, except its nuclear missile. Launch weight: 7,000kg. Length 10.7m.



←——————————1——————————→
←2——→←3→←——4——→←————5————→←——6——→←7→←8→←——9——→

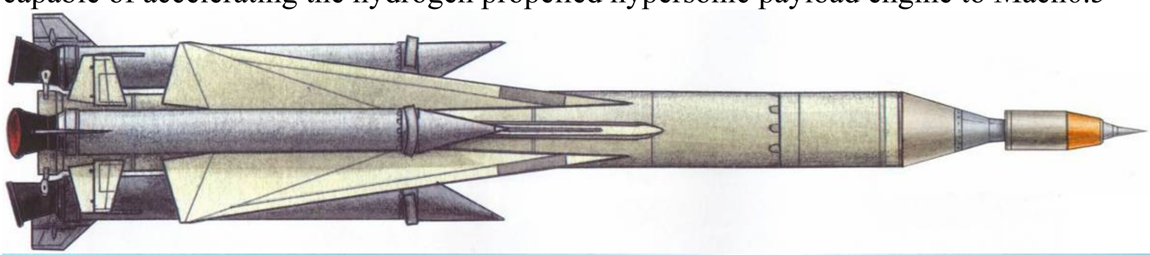
1. **4pcs I. I. Kartukov - 5S25 PRD solid fuel booster.**
   Launch weight: 3,100kg
   Total thrust: 1,500kN
   Burn time: 4s
2. **S. Izotov - 5D67 ZRD digitally programmable liquid fuel sustainer, steering fins.**
   Thrust: 32~100kN (depending on program)
   Burn time: 44~100s (depending on program)
   Maximum Range: 240km (255km for subsonic targets)
   Altitude (min/max): 300-40,800m
   Max missile speed: Mach6.5
   Max target speed: Mach4
3. **Onboard electrical power source**
4. **TG-02 “Samine” fuel (“G” substance) tank.**
   Weight / Composition: 586kg – 700l / mixture of xilidine, and triethylamine.
   50% $C_8H_{11}N$, 50% $C_6H_{15}N$
   *Oily liquid, with color from yellow to dark-brown, and an odor typical for satured animes. Strong nerve agent, fatal concentration in air is: 18mg/liter!*
5. **AK-27P “Melanj” oxidizer (“O” substance) tank.**
   Weight / Composition: 1680kg – 1050l / Nitric Tetroxide in solution with Nitric Acid, with Phosphoric and Fluoric acid inhibitors.
   26±2% $N_2O_4$, 69,5% $HNO_3$, 0,1% $H_3PO_4$, 0,4±0,1% HF, 1,2±0,5% $H_2O$
   *Orange-brown, evaporating liquid. Self ignites combustibles. Highly corrosive, only few materials can withstand its effect: chromium steel, pure aluminum, glass, and for a short period, some rubber mixes.*
6. **5B14S Warhead**
   Weight (explosive): 217 kg (90 kg)
   Fragments: 21,000pcs 3.5g and 16,000pcs 2g steel balls.
7. **5A43 autopilot, 5E23A SRP onboard digital flight computer**
8. **5G24E GSN Continuous Wave semi-active seeker**
9. **Radome**

## 5V28M V-880M (SA-5C Gammon) Surface to Air Missile

Fielded from 1987, the first missile type of the **S-200D Dubna (SA-5C Gammon)** system, with extended maximum range of 300km. As the Cold War ended, only 15 batteries were produced.

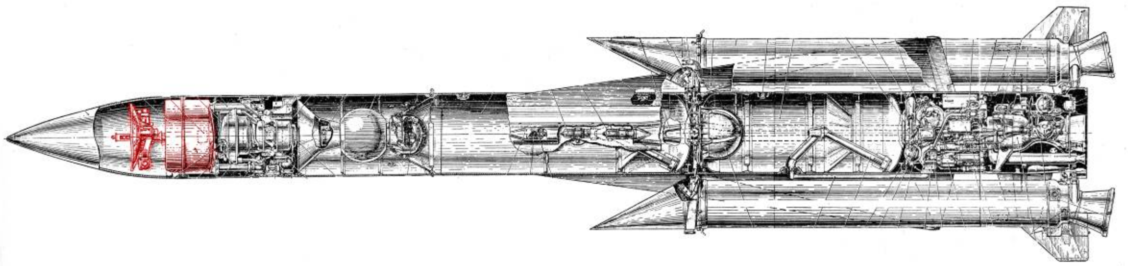
## 5V28 V-880GLL Cholod Hypersonic Testbed

From 1991, the 5V28 was used as a hypersonic test bed at the Sary-Shagan test range, capable of accelerating the hydrogen propelled hypersonic payload engine to Mach6.5



## 5G24E GSN Continuous Wave Semi-active Seeker

The semi-active seeker (red) is located in the nose of the V-880E missile.

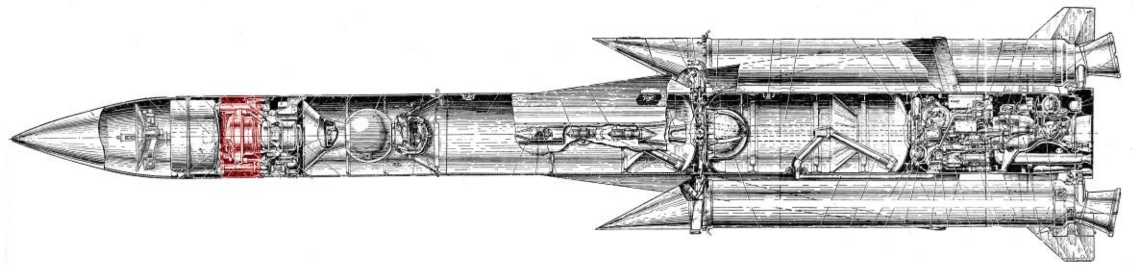


Traditional command guidance method used by earlier Soviet SAM systems…
*S-25 Berkut (SA-1 Guild)*
*SA-75 Dvina (SA-2A Guideline)*
*SA-75M Dvina (SA-2B/F Guideline)*
*S-75 Desna (SA-2C Guideline)*
*S-75M Volhov (SA-2E Guideline)*
*S-125 Neva (SA-3 Goa)*
*2K11 KRUG (SA-4 Ganef)*
… has deteriorating target tracking accuracy beyond ranges of 50km (27nm).
The continuous wave semi-active guidance has several advantages, keeping the same accuracy at any distance, and being resistant of ground echos, chaff and noise jamming, (as the jammer is only acting as a homing beacon for the missile), but there are several disadvantages also…

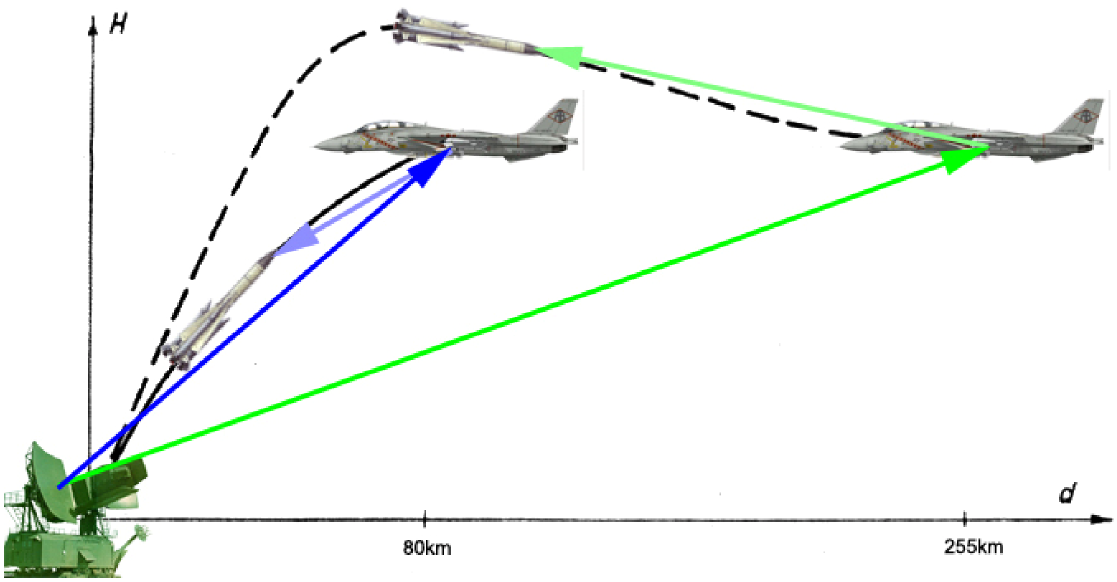

The first disadvantage is the complex, heavy and expensive missile design. The second is that the limited psychical space in the nose of the missile limits the seeker size and thus its sensitivity, reducing the missile's lock-on and effective ranges against small targets. The GSN has a lock-on range for small sized targets (MiG-21) around ~130km (~65nm).

## 5E23A SRP Onboard Digital Flight Computer

The 5E23A SRP digital flight computer (red) is located in the nose section of the V-880E missile, behind the 5G24E GSN.



The 5E23A SRP digital flight computer can command two flight profiles, depending on the target's distance.



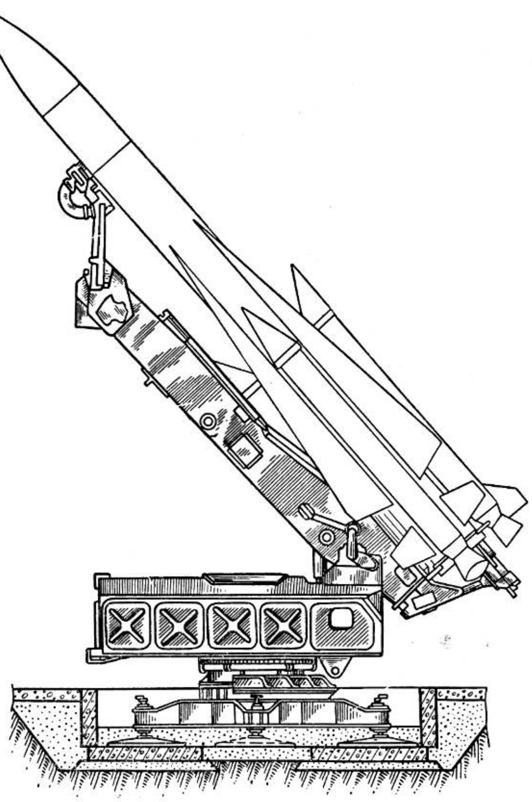

If the target is closer than 80km, the missile will fly a proportional guidance profile from launch, using a low thrust program to accelerate to supersonic speeds (above Mach 3). This conserves fuel, and reduces heating caused by the friction in the dense atmosphere.

If the target is further than 80km, the missile will fly combined guidance profile.
After launch, it will climb at a constant 48° in elevation for 30s, to get out of the dense atmosphere, and then it will arch over, and accelerate to hypersonic speed (above Mach 6) with a maximum thrust program. This way it will collect enough momentum for the long, unpowered descent towards the target after the fuel exhausted. During this phase it uses the proportional guidance method.

The selection of the missile guidance program is done automatically by the Plamya-KV CVM (digital computer of the target illuminator radar) depending on the target parameters, and downloaded to the SRP (digital computer onboard of the missile) before launch.

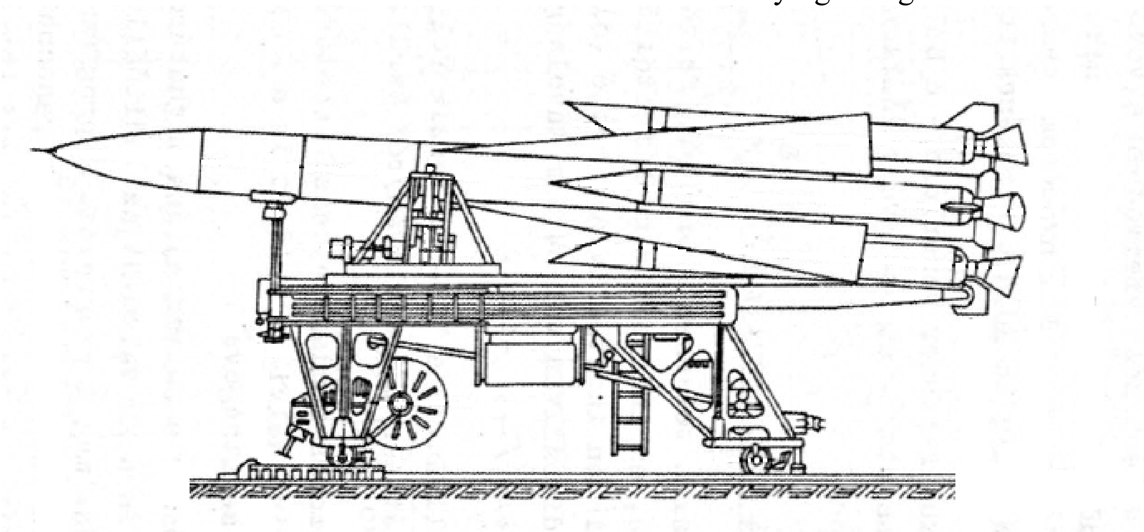
## 5P72VE PU launcher

The S-200VE Vega-E battery has six 5P72VE PU launchers, with one ready to launch missile per launcher. The launcher elevates the V-880E missile to 48° in elevation and turns to the target's azimuth for launch. At the same time the missile's GSN is locking onto the energy reflected from the target, illuminated by the RPC.

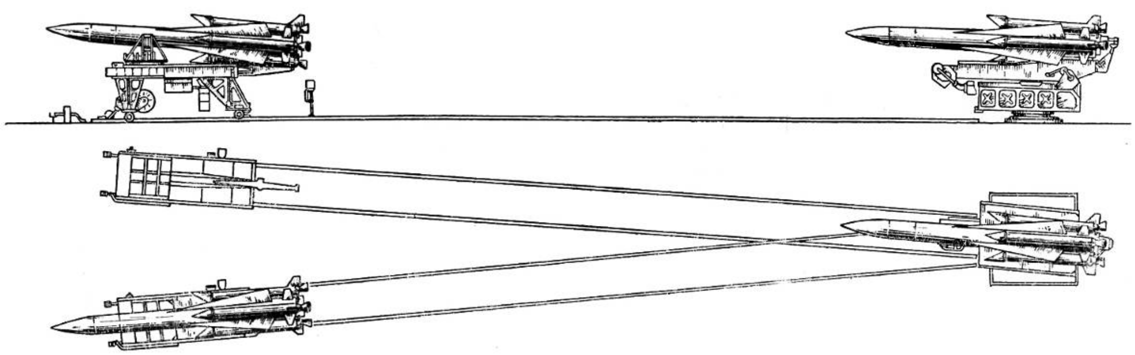


## 5Yu24ME ZM rail loader

The ZM is a rail-based automatic missile loader vehicle carrying a single missile.

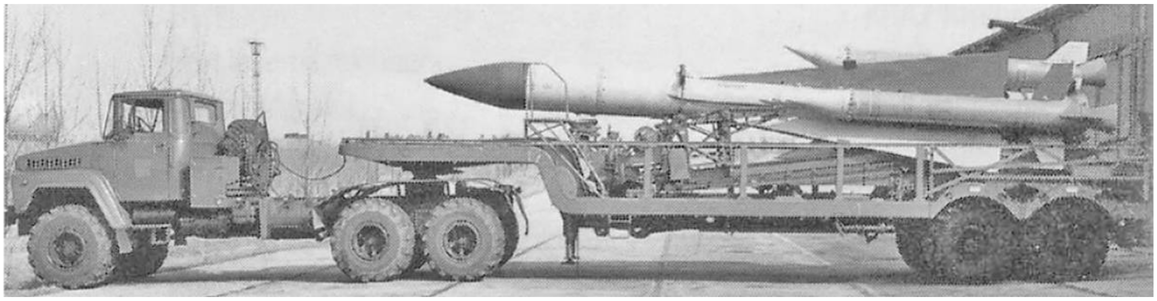


Each of the six launchers (PU) in a battery has two 5Yu24ME rail loaders, providing 2 reserve missiles (altogether 12 per battery).



## 5T82M1E TZM missile transporter-loader

The TZM is a missile transporter-loader semi-trailer, towed by a KRAZ-260 truck. The missile is transported, and loaded from the TZM (missile transporter-loader) to the PU (launcher) directly. Each battery has 6 TZM vehicles.



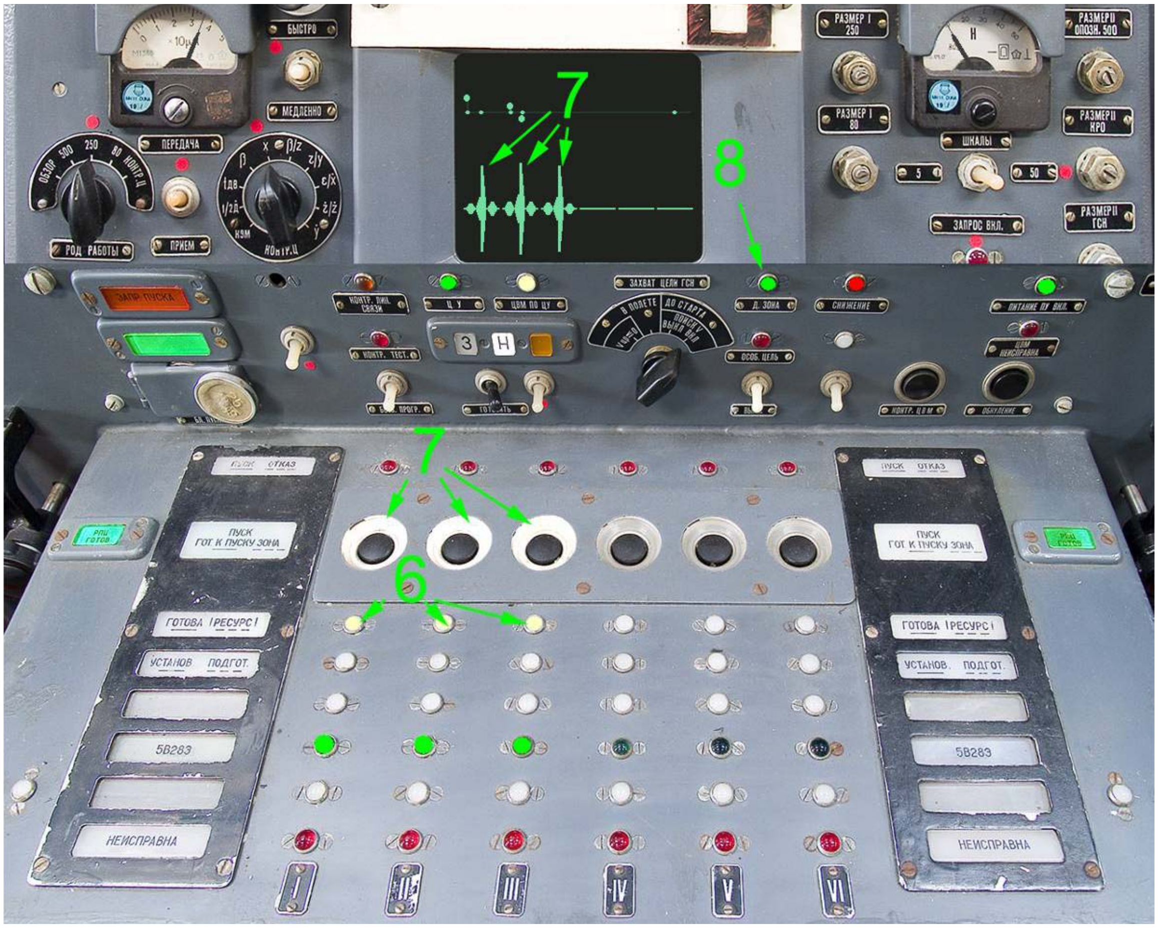
## Preparation of the 5V28E V-880E missile

(Press the “W” button on your keyboard to call up Target Acquisition Officer’s KI-2202V panel)

By clicking on the mode selector with the left mouse button, we switch the system in to “**БР**” (war mode).
By clicking on the red “**ТРЕВОГА**” (alert) button, we can sound the alarm.

(Push the “Z” button to call up the Fire Control Officer’s KI-234V, KR-264V panels)


The six columns represent the six launchers of the Vega system, displaying their status.
1. We can select the number of missiles to be prepared, with the “**ГОТОВИТЬ**” (prepare) switch. (“**3**” - 3, “**Н**”- All)
2. If the missile is on the ZM (rail loader) instead of the PU (launcher), it will start the automatic loading process, and the “**УСТАНОВ.**” (load) lamp will illuminate. As these missiles are not connected yet, the signal from their GSN (semi active seeker head) is missing. (3)
4. If the missile is on the PU (launcher), it will start the gyroscope spin up, and the “**ПОДГОТ.**” (prepare) lamp will flash.
5. As these missiles are connected to the launcher the “**5В28Э**” (5V28E) green lamp will illuminate, and the signal from their GSN (semi active seeker head) can be seen.




6. If the missile preparation for launch is finished, the "**ГОТОВА**" (ready) lamp will illuminate. If this is the last missile (both ZM of the PU is empty), the "**|РЕСУРС|**" (resource) lamp will flash.

7. As the GSN antenna (semi-active seeker head) is much smaller than the RPC (target illuminator radar), it needs a much more powerful received signal to be able to lock on the target. When the received signal strength is enough (more than **25dB**), the missile can start auto tracking the target, and the ring around the fire buttons will illuminate.

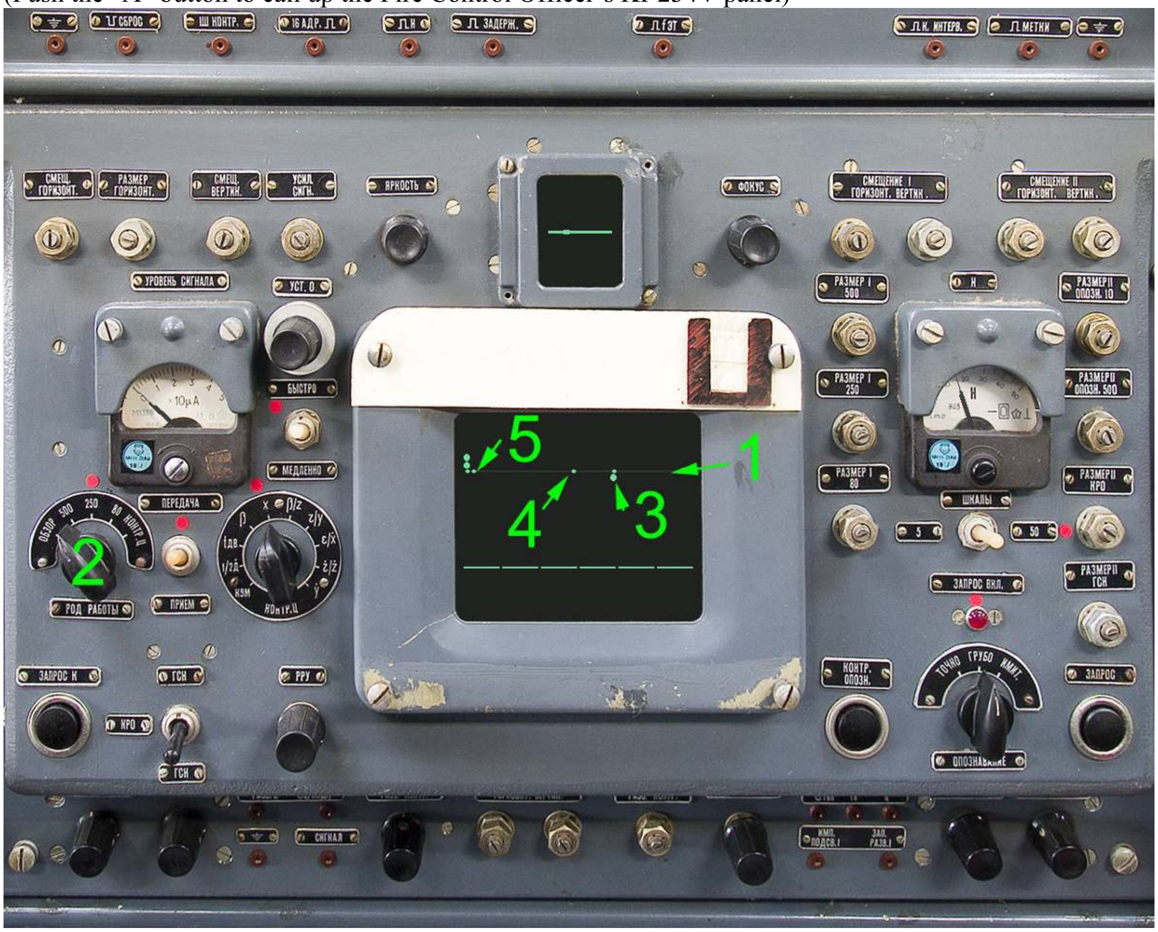
8. If the target is in the missiles firing range, the "**Д. ЗОНА**" lamp will illuminate. If the received signal strength is over 25dB, but the target is outside of the firing range, the ring around the fire buttons (7) will flash.


When the RPC is auto tracking the target, the "**РПЦ ГОТОВ**" will illuminate, and we can start assessing the signs of the launch indicator.

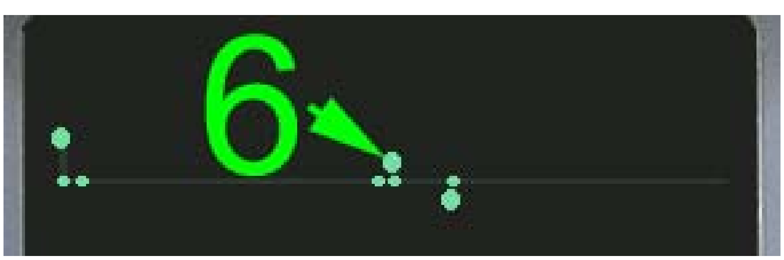
## *Understanding the Launch Indicator*

The signs of the launch indicator are calculated, and drawn by the Plamja-KV CVM (digital computer).

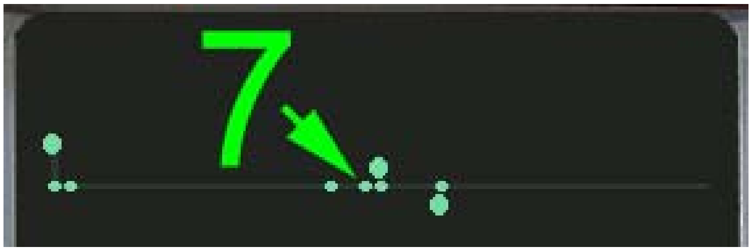
(Push the “A” button to call up the Fire Control Officer’s KI-234V panel)



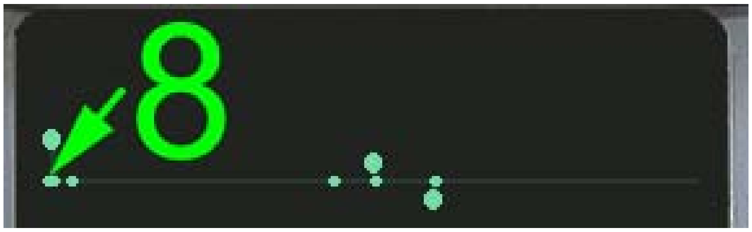

1. The launch indicator is the upper line of the screen.
2. The displayed range can be set to 500km-250km-80km. 0km is at the left, selected range is at the right of the launch indicator line.
3. Negative spike is the target.
4. Right dot on the line is the maximum missile range for supersonic targets (240km).
5. Left dot on the line is the minimum missile range (17km).




6. A small positive spike will indicate the missile-target impact range, if it is closer than 255km. In case the target is subsonic, we could launch now.

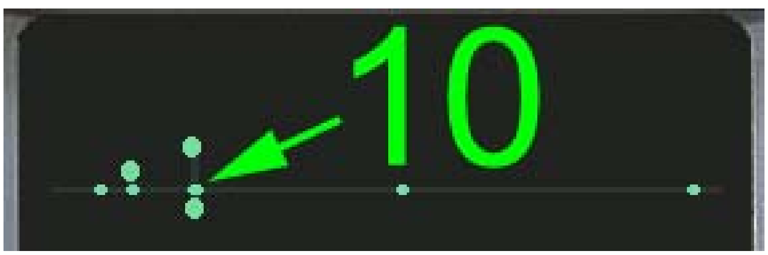



7. If the target is flying below 7km, the missile maximum effective range is reduced, and the right dot will indicate it, while its original place will have a flashing dot, indicating 240km.




8. If the target is flying above 20km, the missile maximum effective range is reduced, and the right dot will indicate it, while the flashing dot will be at the left side of the line.

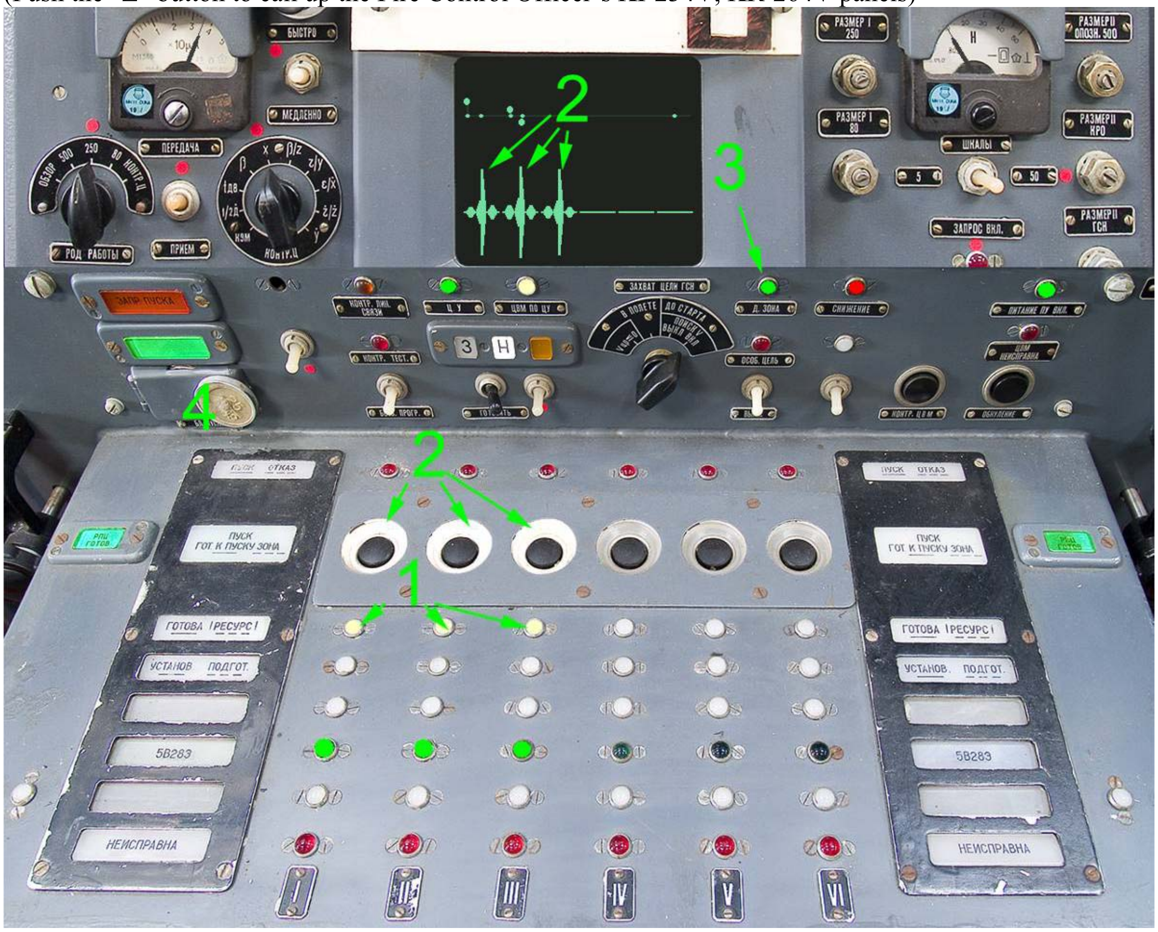

9. After launch, the big positive spike will indicate the launched missile, and the target impact point. This point will be recalculated, if the target maneuvers.




10. When the target reaches the missile-target impact point, we can expect that the missile has reached the target.

# Ну Давай! ПУСК!

(Push the “Z” button to call up the Fire Control Officer’s KI-234V, KR-264V panels)




When all the launch requirements are met…

1. Missile is reached ready to launch state.
2. Missile is receiving enough signal strength from the target to auto track it.
3. Target is at the firing zone.

… we should break the security seal, to access the “**БЛ. ПУСКА**” (launch safety) button. (4)


4. By pressing the "**БЛ. ПУСКА**" (launch safety) button, and the launch button (5) after each other (within few sec), we initiate the missile launch.
(In reality these two buttons should be pressed parallel)

5. The missile is disconnected from the launcher, and the onboard power supply is started. Within 2 second, the onboard electrical power generator is at full speed, and the solid boosters are ignited. After 3 seconds of the ignition, they accelerate the missile over Mach3. From that point, depending its downloaded digital program, the missile will either keep its speed around Mach3 (for close targets to avoid overheating caused by friction), or continue acceleration, and climb to reach Mach6.5.
At the later case, it will exhaust its fuel at about 80km downrange, and starts it's long unpowered descent towards its target.
At 240km downrange, and over 3 minutes of flight, its speed is still around Mach3.

6. The missile-target impact point is shown on the launch indicator.

7. The Plamja-KV CVM (digital computer) is calculating the ideal salvo launch period depending on target parameters.

As the missiles are guiding themselves, we can launch as many, as we want in a salvo. The recommendation is to launch 2 missiles against big non-maneuvering targets, and 3 against small nimble fighters. It is not recommended to launch more than 3 missiles in a salvo against the same target, as if it can avoid 3 missiles, than the chance to hit it with the fourth are very low.

## *Observing the Result of the Shooting*

Several factors needed to be observed, to assess the result of shooting:
(Push the “A” button to call up the Fire Control Officer’s KI-234V panel)


8. After launching the salvo against the target, we switch the launch indicator from “**ГСН**” (GSN - semi active seeker head) display to “**KPO**” (KRO - missile flight status receiver)

9. During this mode, the range is displayed as dots, 20km apart, and the KRO receiver noise is displayed.


10. If the missile would loose its target track during flight, it will start to transmit signals to the RPC, that would be displayed as positive spike.

If the missile hit the target…
- no KRO signals during flight
- target reached the impact point
… its speed and altitude will decrease.

# Special Shooting Circumstances

## *Target Angular Velocity is less than 100m/s, or Receding Target*

The missile's GSN (semi active seeker head) cannot track target if the target's speed is below 100m/s, while the missile is stationery, so it should acquire after launch.

(Push the "Z" button to call up the Fire Control Officer's KI-234V, KR-264V panels)


1. Before launch, we set the missile GSN to acquire the target after launch, by setting the "**ЗАХВАТ ЦЕЛИ ГСН**" (GSN target acquisition mode) switch to the leftmost "**В ПОЛЕТЕ Vцр≤0**" (during flight, target velocity≤0).

2. In this case, the GSN will be unable to auto track the target before launch.

3. To be able for the GSN to auto track the target after launch, the received signal strength should be over **34dB,** a significant increase (almost x10!) of that required for a high-closure target.

## *Noise Jamming*


Noise jamming pods, used since the middle of 60’s, are suppressing the radar echo of the carrier aircraft with strong noise, denying  range information for the fire control radar.

Noise jamming targets can be acquired in elevation and azimuth, but not in range or speed..



1. Metric wavelength noise jamming.
2. Centimeter wavelength noise jamming.
3. The “**ПОМЕХА**” (jamming) switch should be turned “**ВКЛ**” (on).

*As one of the primary goals of the Vega system is to kill standoff jammers, it has several ways to overcome jamming. Here we only discuss one method.*

4. By clicking on the “**АС3**” switch, the “**φ**” lamp will illuminate, indicating that the system is in AS-2 mode (elevation and azimuth tracking only).
5. By holding down the left mouse button over the range wheel , and moving it right-left, we set realistic target altitude (for example 10km) on the “H” instrument of Fire Control Officer’s KI-234V panel (Push the “A” button to call it up).
6. By clicking the “**ВКЛ. АС РПЦ**” (full target tracking) we turn on the CVM (digital computer) target tracking.

## *Shooting at Noise Jamming Targets*

(Push the “Z” button to call up the Fire Control Officer’s KI-234V, KR-264V panels)


7. Before launch, we set the missile GSN, by setting the “**ЗАХВАТ ЦЕЛИ ГСН**” (GSN target acquisition mode) switch to “**ДО СТАРТА ПОИСК V ВЫКЛ**” (Home On Jam).

8-9. Launch missiles as if the target were non-jamming.